Acelerometría

Método para cuantificación de la carga en el deporte

6387. NUEVAS TECNOLOGÍAS EN EDUCACIÓN FÍSICA Y DEPORTE
Curso 2023-2024

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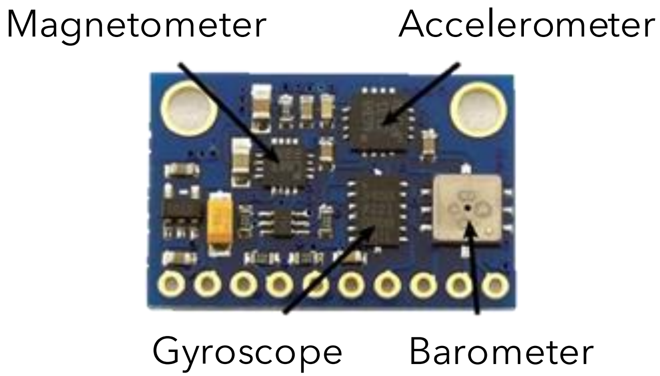
1. INTRODUCTION

A brief history

- The development of accelerometry began in the 1920s when McCollum and Peters developed the first sensor to measure accelerations in dynamometers, airplanes, and bridges.
- The problem to use the first accelerometers in team sports are the big size.

- This problem disappeared in 1990s with the appearance of microelectromechanical systems (MEMS).
- MEMS are defined as the technology of microscopic devices (generally between 20 micrometers to a millimeter) with moving parts.
- They usually are composed of a central unit that processes data (microprocessor) and several components that interact with it (microsensors) that are made of silicon, polymers, metals or ceramics.
- The most used microsensors in sport science are accelerometers, gyroscopes, magnetometers and barometers.



(Walter, 2007)

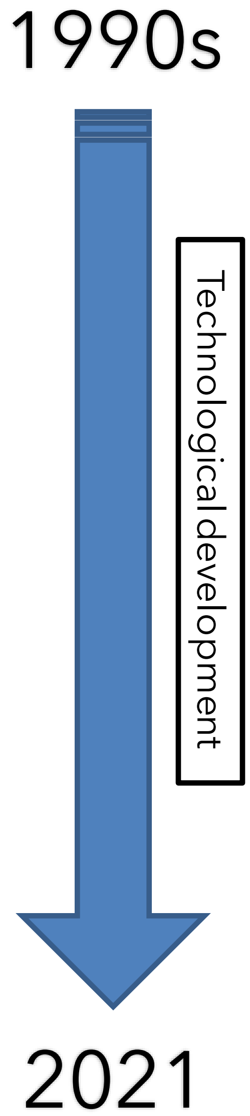
1. INTRODUCTION

Applications of accelerometers

- Thanks to MEMS development, accelerometers decreased in size, cost and power consumption as well as increased their accuracy and reliability.

- So, an increasing in its application has been produced exponentially in different sectors from 1990 such as:

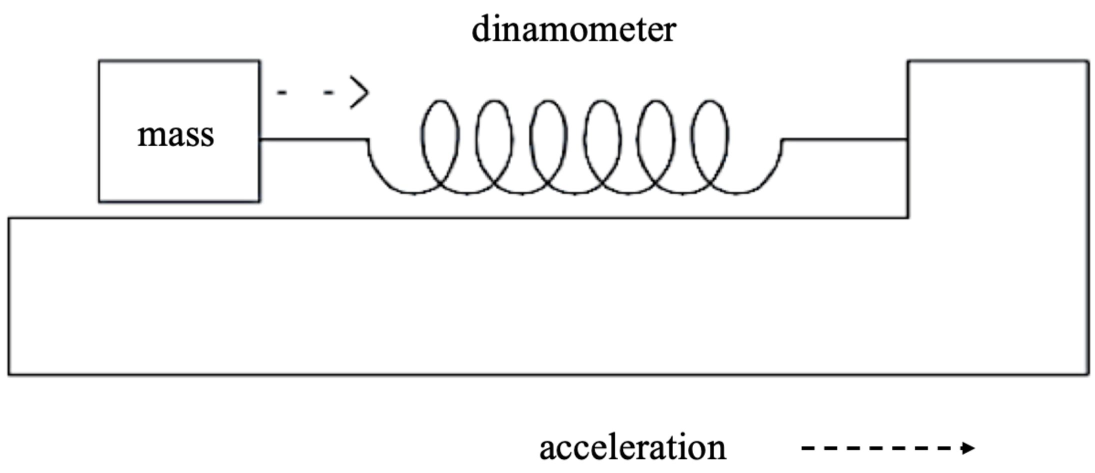
  ✓ Engineering
  ✓ Medical technology
  ✓ Electronic articles
  ✓ Physical activity
  ✓ Team sports monitoring



(Meng et al., 2007; Otto et al., 2006; Liu et al., 2009; Bonomi et al., 2009; al., Gómez-Carmona et al., 2020a)

Accelerometer's system

- An accelerometer is an electrical device that directly measures the applied acceleration acting along a sensitive axis.
- There is a different type of accelerometers, but each uses different mechanisms, designs, and fabrication techniques that are variations of the dynamometer-mass system shown in Figure 1.
- The most widely used accelerometers for the study of human movement are piezoresistive, variable capacitance, MEMS and piezoelectric.

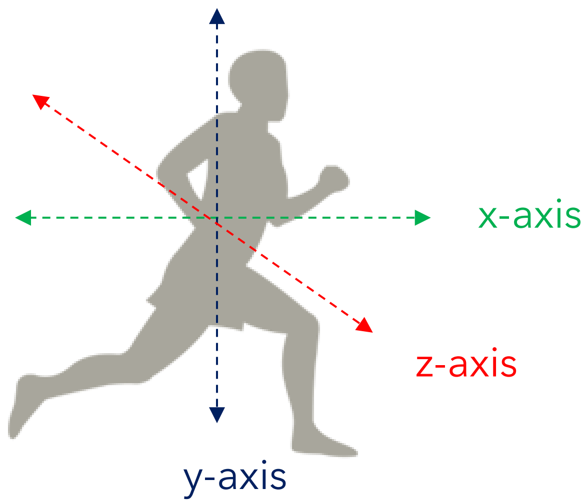


(Sijtsma et al., 2013; Busa and McGregor, 2008; Murphy, 2009)

Acceleration

- Acceleration (a) can be defined as a change in velocity with respect to time (a= meters per second squared [m*s2]) and is measured in units of gravitational acceleration (g, 1g= 9.81 m*s2)
- Accelerometer can be uniaxial (x or y axis), biaxial (x and y axis) or triaxial (x, y and z axis).
- X axis represent medium-lateral acceleration (horizontal movement), Y axis vertical acceleration (product of gravity) and Z axis anteroposterior acceleration (rotational movements).
- Triaxial accelerometers are considered more accurate than uniaxial and biaxial accelerometers
- The accelerometer data is bi-directional when it is first produced, which means that the sensors can monitor acceleration in both directions along the sensitive axis.
- The data from triaxial accelerometers can be combined into a single summarized called resultant vector, represented in Equation 1.

$$A = (v_1 - v_2) / (t_1 - t_2)$$

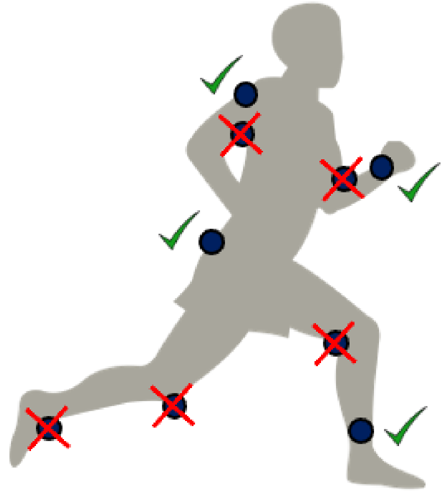


$$\textit{Resultant vector} = \sqrt{x^2 + y^2 + z^2}$$

(Chen and Bassett, 2005; Waldron et al., 2011)

4. PRACTICAL CONSIDERATIONS

- **Accelerometers' attachment**



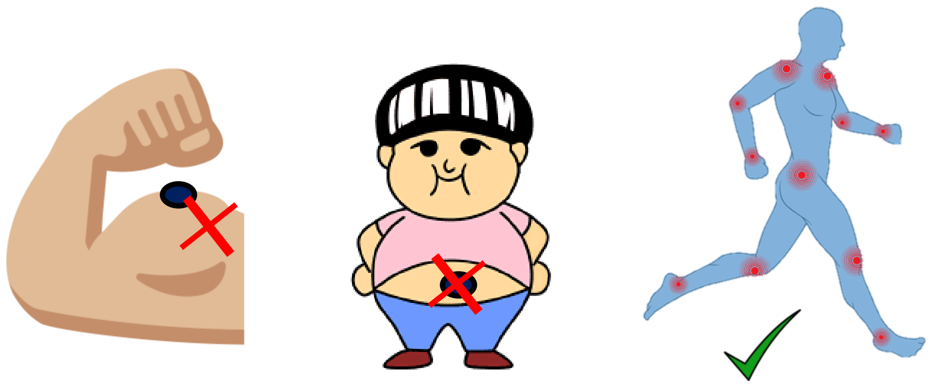
✓ Not limit the range of movement of the athlete.

✓ Attachment should be the most comfortable as possible.

✓ The distance between device and human body or object should be the nearer as possible to avoid noise.

✓ Not use elastic materials.

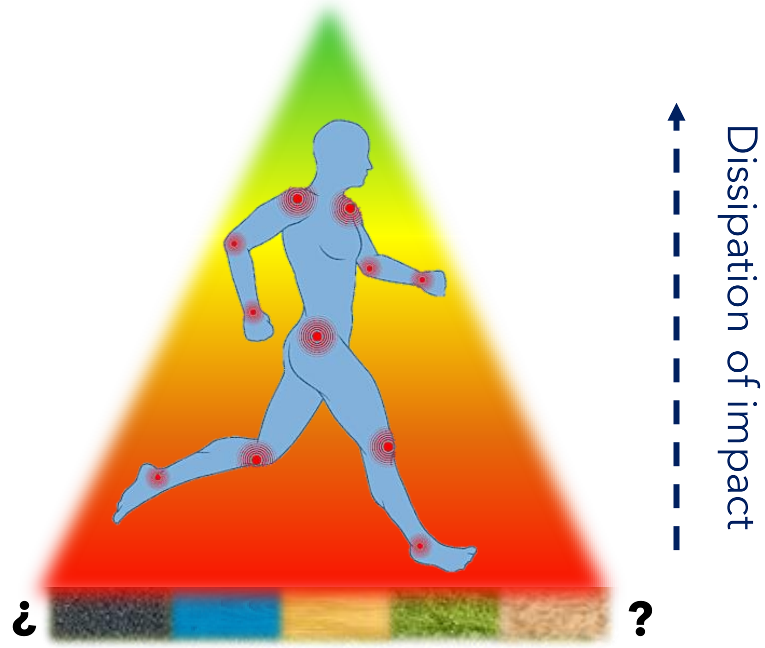
✓ Avoid areas of human body with soft tissues (fat or muscle), their placement at joints is advisable.

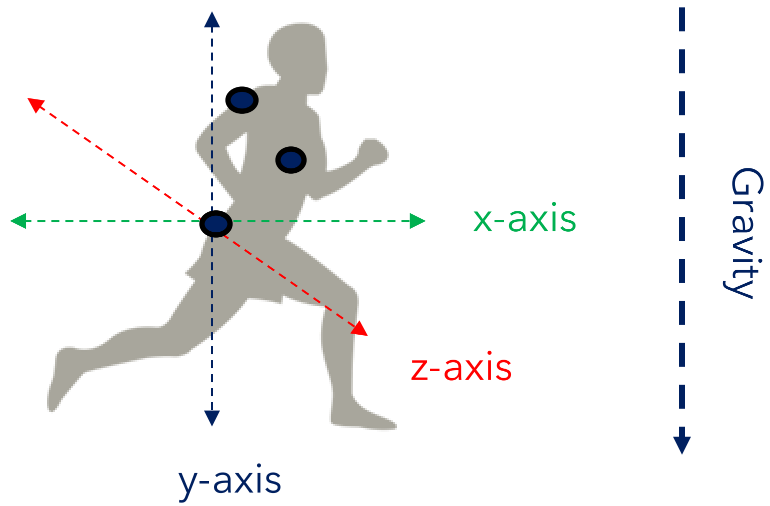


(Boerema et al., 2014; Edwards et al., 2018)

- **Body Location**

  - ✓ Should be attached the nearest as possible to the object or body segment of analysis.
  - ✓ The impacts suffered during sports are absorbed along the human body, presumable by the musculoskeletal structures.
  - ✓ If it's located in the center of mass, it is aligned with the anatomical axes of the human body.
  - ✓ The most common locations are scapulae, center of mass or sternum.
  - ✓ The highest contribution to resultant vector is from the vertical axis in sports, due to the influence of gravity.





(Hall, 2014; Gómez-Carmona et al., 2020a; Gómez-Carmona et al., 2020b; Nedergaard et al., 2017; Cormack et al, 2014)

4. PRACTICAL CONSIDERATIONS

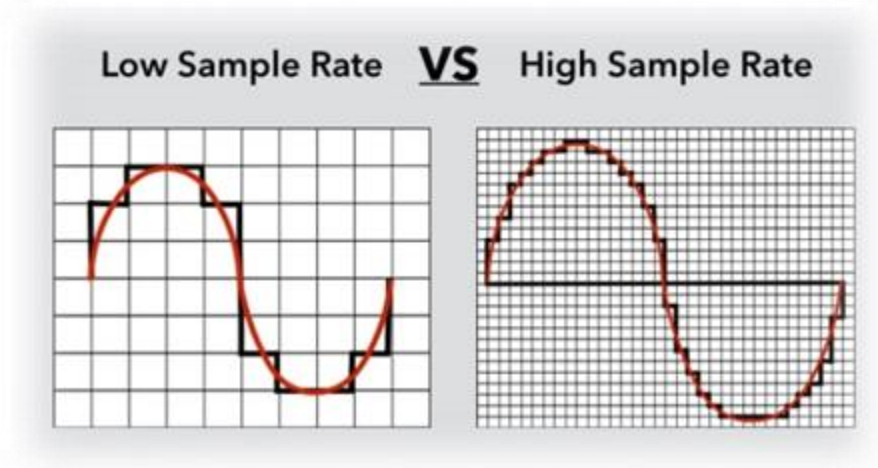
- **Sampling frequency**

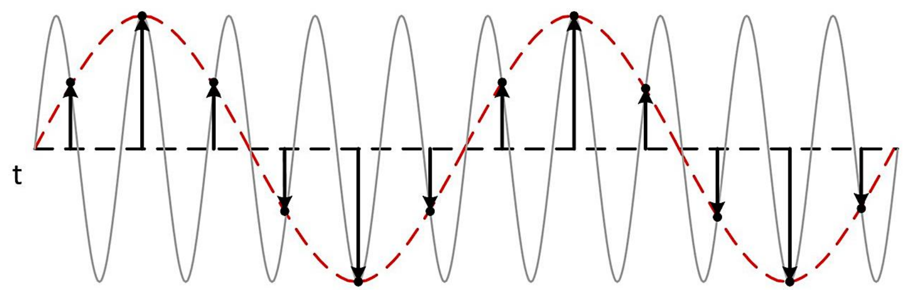
  ✓ It is important to ensure high data quality.

  ✓ Lower sampling frequency es related to lower accuracy.

  ✓ To ensure high data quality, the Nyquist theorem should be considered, so the sampling rate must be at least two times the highest frequency of a range of interest.

  ✓ A minimum of 100 Hz is necessary to detect human movements in the sport context with acceptable accuracy and reliability.





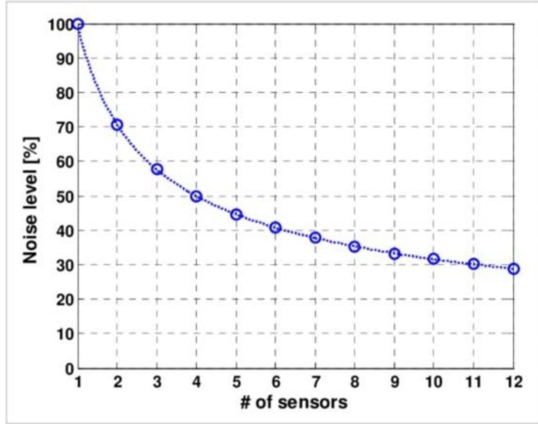
(Malone et al., 2017; Stevens et al., 2014; Derrick and Robertson; Migueles et al., 2017; Gómez-Carmona et al., 2020c)

4. PRACTICAL CONSIDERATIONS

- **Number of accelerometers**

  ✓ Inertial measurement units (IMUs) can be formed by one or multiple accelerometers.

  ✓ Devices with more than one accelerometer are more reliable (40-60%) due to redundancy principle, a down-sampling method to fusion data from multiple accelerometers.

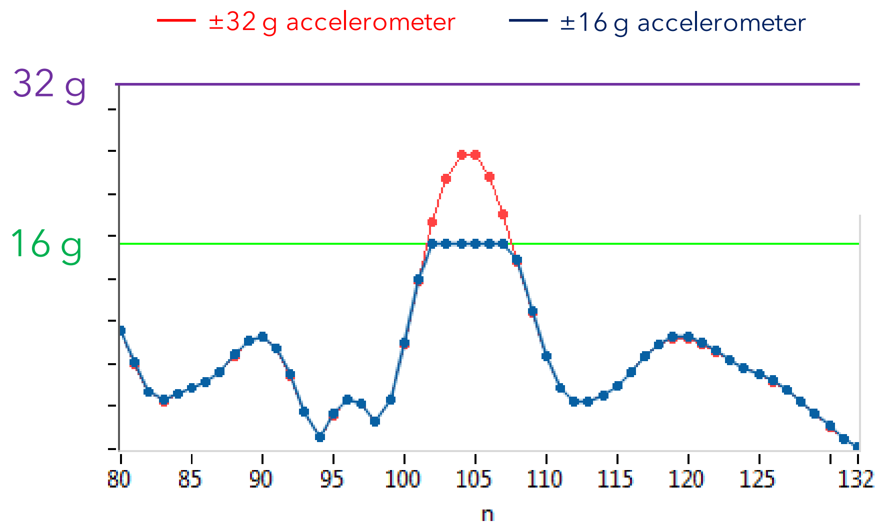


- **Output range**

  ✓ Defined as the level of acceleration supported by the sensors in ±g force.

  ✓ It is important due to an acceleration higher than the output range cannot be register.

  ✓ In sport science, accelerometers typically present an output range of ±16g.

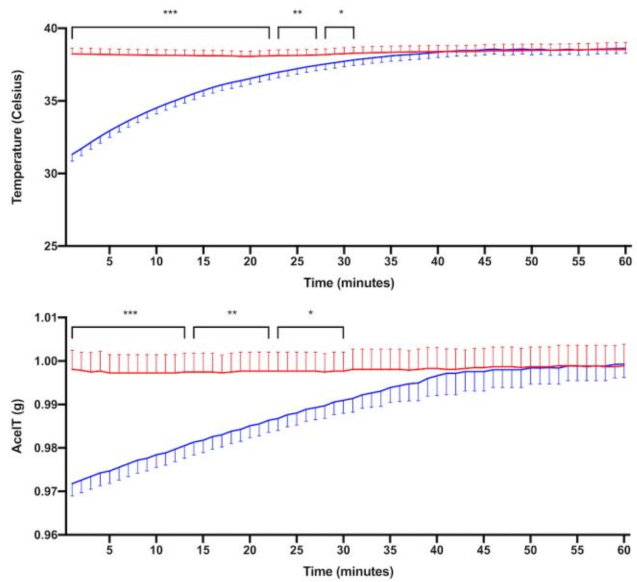


(Waegli et al., 2010; Gómez-Carmona et al., 2020a)

- **Working temperature**

  ✓ A constant temperature during the monitoring is needed, following the principle of temperature feedback set by the manufacturer.

  ✓ Temperature drift significantly affects accelerometer data, especially when the temperature is colder than the optimal.

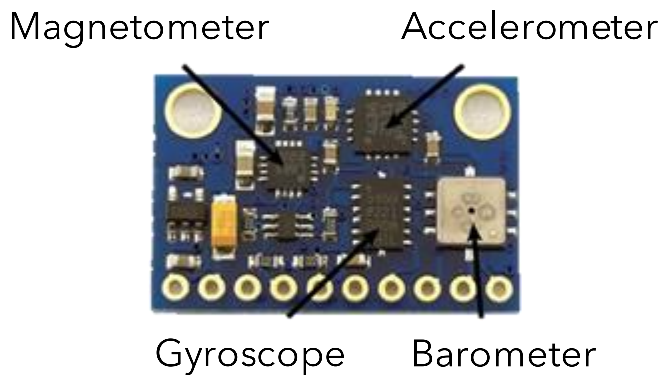


- **Influence of materials**

  ✓ Magnetic materials influence the accelerometers measurement.

  ✓ This fact is produced due to the magnetometers included in IMUs improve the measurement of accelerometers.

  ✓ Magnetometer complements accelerometers by filtering the movements' orientation and detecting different movements of the same body part that gives an extra scale with no deviation over time.



(van Hees et al., 2014; Awolusi et al., 2018)

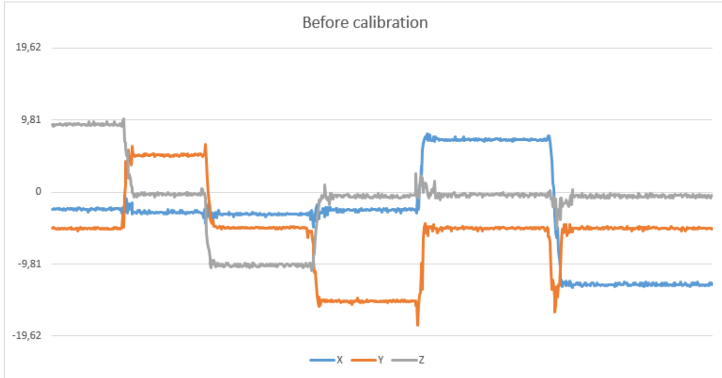
4. PRACTICAL CONSIDERATIONS

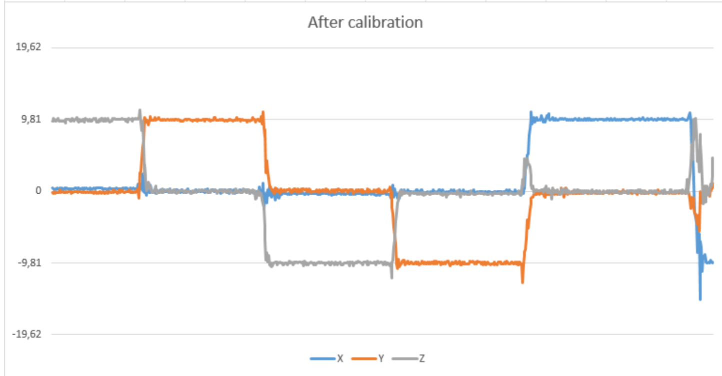
- **Previous calibration**

  ✓ Accelerometers suffer a drift over time.

  ✓ A recalibration process is necessary to improve the accuracy and to obtain an acceptable quality of measurement.

  ✓ The assessment of accuracy should be performed in the same conditions of register.



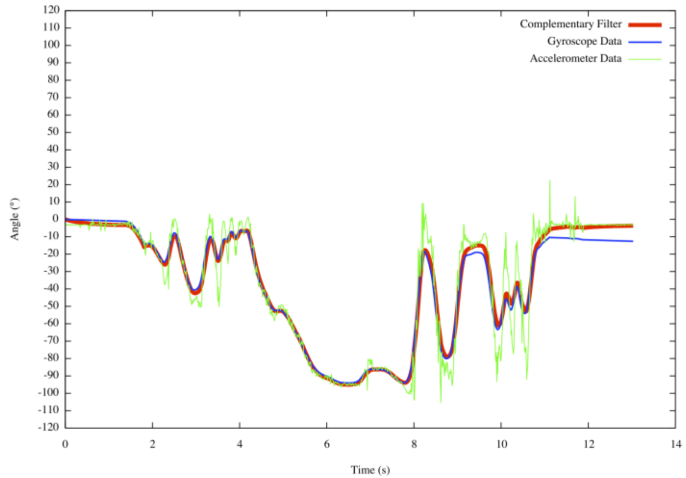


- **Data processing**

  ✓ To improve the accuracy, low-pass filters with various cut-off frequencies are used.

  ✓ In addition, companies use ad-hoc algorithms to compensate for drift errors.

  ✓ For this reason, accelerometer data between devices cannot be compared due to the different filters and algorithms.



(Fong et al., 2008; Bergamini et al., 2014; Gómez-Carmona et al., 2020a)

5. SPORTS TRAINING AND WORKLOAD

- ✓ **Sports Training:** Process of systematic execution of exercises to improve the physical capacities and specific sports abilities.
- ✓ **Exercise workload:** Manipulated variable to achieve the desired adaptations, considering it as the total stimuli to which the athlete was exposed. It depends on organization, quality and quantity.

How it can be measured?

- ✓ **External load:** Mechanical and locomotor stress suffered by an athlete during activity.
- ✓ **Internal load:** Biological reaction of the athlete's body to the external workload during activities.

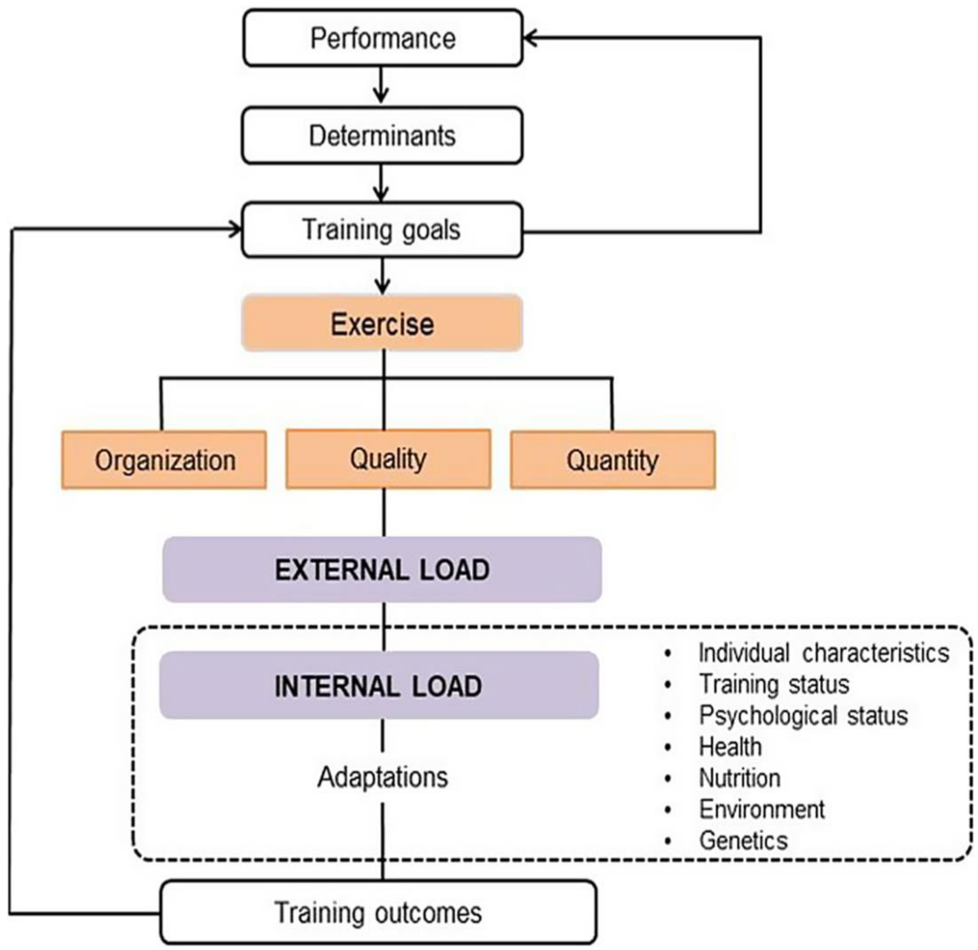


Figure 1. *Theoretical framework of the training process (extracted from Impellizeri et al. 2019)*

IMPORTANT!! The athlete's response and **his/her adaptations** are **specific/individual** according to nature, intensity, duration and task performed.

(Bourdon et al., 2017; Coutts et al., 2018; Fox et al., 2018; Halson et al., 2014; Impellizeri et al., 2019)

5. SPORTS TRAINING AND WORKLOAD

LOAD	VARIABLES	INSTRUMENTS
✓ **External load:** Mechanical and locomotor stress suffered by an athlete during activity.		
• **Kinematical load:** Volume and intensity of movements performed by the athlete.	• Distance • Speed • Accelerations • Change of direction • High-intensity actions.	**Tracking technologies** • GNSS • LPS • Video-tracking
• **Neuromuscular load:** Force executed by the athlete, as a result of the interaction with gravity and teammates or opponents.	• Jumps • Impacts • Ground reaction forces • Steps • Accumulated workload (e.g., PlayerLoad, BodyLoad)	**Microsensors** • Accelerometer • Gyroscope • Magnetometer
✓ **Internal load:** Biological reaction of the athlete's body to the external workload during activities. Heart rate telemetry and variability	• Blood lactate • Oxygen consumption • Muscle oxygen saturation • Rated of perceived exertion • Wellness (Sleep, muscle soreness, humor, fatigue and stress).	• Chest band • Muscle oximeter • Gas analyzer • Scales and questionaries.

(Buchheit et al., 2018; Gómez-Carmona et al., 2018; Gómez-Carmona et al., 2020a; Granero-Gil et al., 2020; McLaren et al., 2018; Oliva-Lozano et al., 2020)

6. ACCELEROMETRY-BASED VARIABLES

Table 1. *Accelerometry-based external workload variables (extracted from Gómez-Carmona et al., 2020a)*

Index	Description	Units	Developing company	Formula
AcelT	Root square of the sum of the accelerations in the three axes of movement.	Meters per second square ($m \cdot s^2$)	None	$\sqrt{(x^2+y^2+z^2)}$
Body Load (BL)	Accelerometry-load based index in the three axes of movement. Following steps are repeated for each acceleration value: (1) Initialize the Body Load count to 0; (2) Root square of the sum of the accelerations in the three axes of movement (x, y and z); (3) Normalize the magnitude vector by subtracting a notional 1G; (4) If the normalized value is less than 0.25G then go to step 2; (5) Calculate the unscaled Body Load (USBL) contribution for this acceleration vector; (6) Calculate the scaled Body load (SBL) considering the accelerometer logging rate (100 Hz) and Exercise Factor (EF); (7) Calculate the total Body Load as the accumulation of the scaled Body Load count.	Arbitrary units (A.U.)	GPS Sports	1. BL = 0 2. $\sqrt{(ay^2+ax^2+az^2)}$ 3. NV = V - 1.0 G 5. USBL = NV + $(NV)^3$ 6. SBL = USBL / 100 / EF 7. BL + SBL
Body Load 2D (BL2D)	Accelerometry-load based index in the two planes of movement (anteroposterior and mediolateral). Same steps as BL but not considering z-axis in the formula.	Arbitrary units (A.U.)	GPS Sports	2. $\sqrt{(ay^2+ax^2)}$
Collisions	For a collision to be detected, the unit was required to be in a nonvertical position, meaning the player was leaning forwards, backwards, or to the left or right. The instantaneous player load was calculated from the sum of the three axes of acceleration. A spike in the instantaneous player load shortly before the change in orientation of the unit was also required for the collision to be detected.	Count (n)	Catapult	Not applicable
Dynamic Stress Load (DSL)	It was calculated as the total of the weighted impacts. Impacts were weighted using a convex-shaped function (approximately a cubic function), an approach similar to the one used in the speed-intensity calculation, with the key concept being that an impact of 4g is more than twice as hard on the body as an impact of 2 g. The weighted impacts were totaled and finally scaled to give more workable values expressed in arbitrary units (AU).	Arbitrary units (A.U.)	StatSports	Not provided
Impacts	Using the magnitude of the 3-dimensional accelerometer values at any time point, impacts were identified as maximum accelerometer magnitude values above Xg in a 0.1-second period in relation to manufacturers' specifications. GPS Sports: 6 ranges of impacts according to the impact intensity: very light (<5.0-6g), light to moderate (6.1-6.5), moderate to heavy (6.5-7.0), heavy impact (7.1-8.0), very heavy (8.1-10.0) and severe (over than 10.1g). StatSports: Values above 2g. RealTrack Systems: Configurable threshold from 1 to 1000 G.	Count (n)	GPS Sports StatSports	Not applicable
IMA	Application of polynomial smoothing curves between the start and end point of identified accelerative events. The magnitudes of such events are subsequently calculated by summing the accelerations under the polynomial curves, measured in terms of delta-velocity.	Meters per second square ($m \cdot s^2$)	Catapult	Not provided

(Gómez-Carmona et al., 2020a)

6. ACCELEROMETRY-BASED VARIABLES

Table 1. *Accelerometry-based external workload variables (extracted from Gómez-Carmona et al., 2020a)*

Index	Description	Units	Developing company	Formula
Impulse Load	Sum of the forces in the medio-lateral, anterior-posterior and vertical plane in relation to gravity.	Newtons (N)	Zephyr Technology	$\sum_{s=1}^{n} \frac{\sqrt{x_s^2 + y_s^2 + z_s^2}}{9.8067}$
Locomotion Efficiency	To assess the within-match patterns of PlayerLoad™ and its individual planes in comparison to the locomotor activities, PLz was made relative to the total distance covered (TDC) as a measure of players locomotor efficiency.	Arbitrary units (A.U.)	Catapult	$\frac{\sqrt{\frac{(up_{t=i+1} - up_{t=i})^2}{100}}}{Total\ Distance\ Covered}$
PlayerLoad™ (PL™)	Change in acceleration in the anterior-posterior (ax) medio-lateral (ay) and vertical (az) planes.	Arbitrary units (A.U.)	Catapult	$\sqrt{\frac{(fwd_{t=i+1} - fwd_{t=i})^2 + (side_{t=i+1} - side_{t=i})^2 + (up_{t=i+1} - up_{t=i})^2}{100}}$
PlayerLoad™ x-axis (PLx)	Change in acceleration in the anterior-posterior (ax) plane.	Arbitrary units (A.U.)	Catapult	$\sqrt{\frac{(side_{t=i+1} - side_{t=i})^2}{100}}$
PlayerLoad™ y-axis (PLy)	Change in acceleration in the medio-lateral (ay) plane.	Arbitrary units (A.U.)	Catapult	$\sqrt{\frac{(fwd_{t=i+1} - fwd_{t=i})^2}{100}}$
PlayerLoad™ z-axis (PLz)	Change in acceleration in the vertical (az) plane.	Arbitrary units (A.U.)	Catapult	$\sqrt{\frac{(up_{t=i+1} - up_{t=i})^2}{100}}$
PlayerLoad™ 2D (PL2D)	Change in acceleration in the anterio-posterior (ax) and medio-lateral (ay) plane.	Arbitrary units (A.U.)	Catapult	$\sqrt{\frac{(fwd_{t=i+1} - fwd_{t=i})^2 + (side_{t=i+1} - side_{t=i})^2}{100}}$
PlayerLoad™ slow (PLslow)	Change in acceleration in the anterior-posterior (ax) medio-lateral (ay) and vertical (az) planes lower than 2G.	Arbitrary units (A.U.)	Catapult	$\sqrt{\frac{(fwd_{t=i+1} - fwd_{t=i})^2 + (side_{t=i+1} - side_{t=i})^2 + (up_{t=i+1} - up_{t=i})^2}{100}}$
Player Load$_{RT}$ (PL$_{RT}$)	Vector sum of the Body accelerometric channel calculated through the sensorial fusion of inertial device sensors (accelerometer, gyroscope, magnetometer) in its 3 axes (vertical, anteroposterior and lateral).	Arbitrary units (A.U.)	RealTrack Systems	$PL_n = \sqrt{\frac{(X_n - X_{n-1})^2 + (Y_n - Y_{n-1})^2 + (Z_n - Z_{n-1})^2}{100}}$ $PL\ acummulated = \sum_{n=0}^{m} PL_n\ x\ 0{,}01$
Player Load$_{RE}$ (PL$_{RE}$)	The player load is calculated and presented as a downscaled (i.e., divided by 800) value of the square sum of the high-passed filtered accelerometer values for the respective axes (X, Y, and Z).	Arbitrary units (A.U.)	ZXY SporTracking	$\frac{(x^2 + y^2 + z^2)}{800}$
Total Load	Total of the forces on the player over the entire session based on accelerometer data alone where aca is acceleration along the anterior-posterior axis, acl is acceleration along the lateral axis and acv is acceleration along the vertical axis, i is the current time and t is time. This is then scaled by 1000.	Arbitrary units (A.U.)	StatSports	$\frac{\sqrt{(aca_{t=i+1} - aca_{t=i})^2 + (acl_{t=i+1} - acl_{t=i})^2 + (acv_{t=i+1} - acv_{t=i})^2}}{1000}$

(Gómez-Carmona et al., 2020a)

7. PRACTICAL APPLICATIONS OF ACCELEROMETRY IN TEAM SPORTS

- **Events or peak demands**

Accelerometer can measure two types of variables:

✓ **Events**: They are considered as the specific technical actions performed by the player during the game. For this purpose, different algorithms have been developed to measure them with high accuracy. These variables are jumps (total, landing and take-off), tackles, steps or rucks, among others.

✓ **Peaks:** They are considered as the high 3-axis g-force registered events during the game. It can be measured in impacts or collisions depending on the manufacturer.

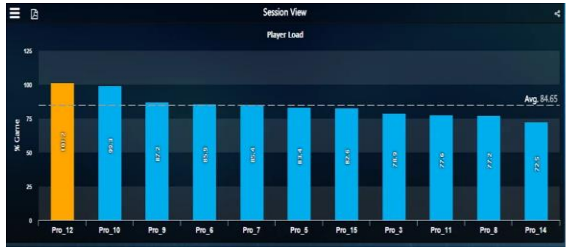
- **Specific thresholds**: Low activity (2G); Moderate impacts (>5G); Severe impacts (>10G).
- **Sports:** Soccer (5G); American or Australian football and rugby (10G). They are specific of physical contacts permitted during the games. Regarding 5G impacts: Soccer (450-600); rugby (900-1200); American football (900-1100).

(Abade et al., 2014; Gabbett, 2015; Gómez-Carmona et al., 2020a; McLellan and Lovell, 2012; Wellman et al., 2017)

7. PRACTICAL APPLICATIONS OF ACCELEROMETRY IN TEAM SPORTS

- **Accumulated demands**

✓ Defined as the cumulated workload during a training or matches.



✓ To calculate these indexes, all follow the same principle: accumulate the difference between the triaxial acceleration at the previous moment and the present moment, dividing the value by the sampling frequency or an arbitrary unit.

✓ The most extended index is PlayerLoad, that is common normalized by total session time (PL/min).

$$\sqrt{\frac{(fwd_{t=i+1}-fwd_{t=i})^2+(side_{t=i+1}-side_{t=i})^2+(up_{t=i+1}-up_{t=i})^2}{100}}$$

✓ The values (PL/min) differ between sports modalities such as: soccer 10.6-13.2±1.5-2.5, netball 9.4-10.6±2.4-3.6, handball 9.18-9.76±0.6-1.4, rugby union 7.6±0.6, hockey 13.8-12.5±1.6-1.0, Australian football 15.1-16.3±0.9-1.4 and rugby 7.2-10.4±0.8-2.0.

✓ Other variables have been developed to analyze specific workload:

- PL_x, PL_y or PL_z: to detect the cumulated workload in each axis, more than 50% is detected in vertical axis (PLy).
- Pl_{slow}: to detect low-intensity workload (<2G). Represents between 35-50% of total workload.

(Beenham et al., 2017; Cormack et al., 2014; Gómez-Carmona et al., 2020a; Pino-Ortega et al., 2019; Read et al., 2017)

7. PRACTICAL APPLICATIONS OF ACCELEROMETRY IN TEAM SPORTS

- **Neuromuscular load and its relationship with injury risk**

  ✓ It is an **useful index** to detect the **individual volume** of demands of the players, and their adaptations.

  ✓ The effect of neuromuscular load in injury risk has been evaluated and proved in different sports such as Australian football, soccer or rugby.

  ✓ High-levels of neuromuscular load provokes **higher injury risk** in **youth** than senior players, especially in matches.

  ✓ Previous research identified that **3-weekly chronic workload** were most related to greater **injury risk**. So, **acute-chronic workload** ratio if use PL or dependent variables **need 3-weekly loads** to obtain **chronic workload**.

  ✓ **Neuromuscular load** has obtained very **high relationship** with serum **creatin kinase**, especially in relation with **accelerations, decelerations, impacts >3G and sprints**.

  ✓ A decreasing in **accumulated workload** during matches were associated with **greater non-contact injury risk**, especially in the **last part** of the match halves (fatigue). In addition, **peak accelerations (>10G)** are strongly related with **contact injuries**.

Figure 3. *Acute:chronic workload vs injury risk (extracted from Blanch and Gabbett, 2016)*

(Barrett et al., 2016; Blanch and Gabbett, 2016; Buchheit et al., 2018; Colby et al., 2014; Gastin et al., 2019; Gómez-Carmona et al., 2020a; Pfirmann et al., 2016)

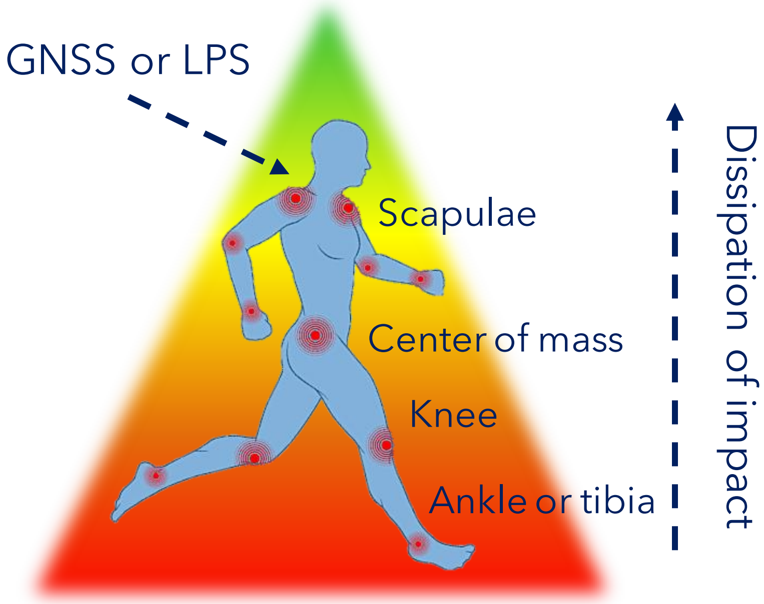
- **Assessment in different anatomical locations**

✓ Inertial devices have been placed at **scapulae** level due to the **most accurate detection of position** coordinates by GNSS or LPM. Only a few devices are optimized to use at center of mass or sternum (no tracking data).

✓ Recent investigations indicated that accelerometers only record the acceleration of the body segment that they are attached to. Therefore, **whole-body acceleration cannot be measured by one device** due to the multi-joint complexity during sports movement.

✓ The study of **accelerations** in the **different joints** and body segments at the **same time** can provide useful information on the **absorption dynamics** of external load by the **musculoskeletal structures**.

✓ A **field-test battery** has developed to evaluate multi-joint external workload profile in **four body locations** simultaneously (ankle, knee, lumbar region and interscapular line) in the **most common displacements** in team sports (curvilinear, linear continuously, accelerations/decelerations, jumps and small-sided games).



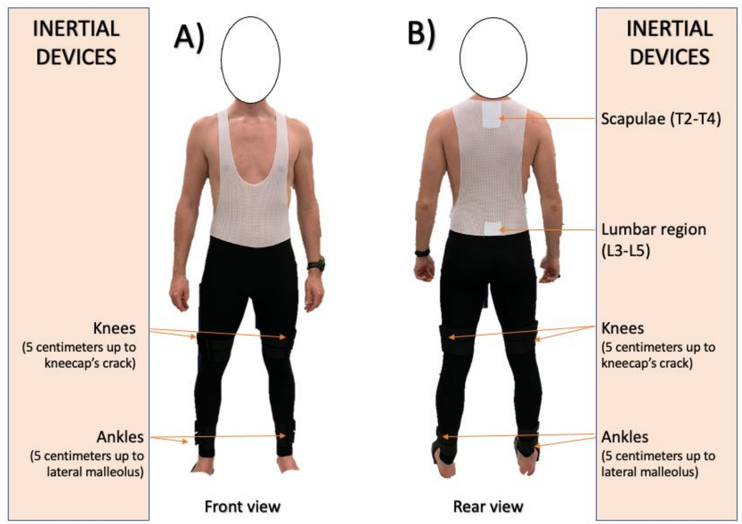


Figure 2. *Vest prototype for multilocation assessment (extracted from Gómez-Carmona et al. 2020d)*

(Cummins et al., 2013; Gómez-Carmona et al., 2020a; Gómez-Carmona et al., 2020d; Morris and Lawson, 2009; Nedergaard et al., 2017)

8. RECENT RESEARCH IN APPLICATION OF ACCELEROMETERS IN SPORTS

RESEARCH ARTICLE

Accelerometry as a method for external workload monitoring in invasion team sports. A systematic review

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RICYDE. Revista Internacional de Ciencias del Deporte
doi: 10.5232/ricyde
Rev. Int. cienc. deporte

RICYDE. Revista Internacional de Ciencias del Deporte
Volume XVII - Year XVII
Pages: 124-139 - ISSN: 1885-3137
Issue 64 - April 2021

https://doi.org/10.5232/ricyde2021.06402

Multi-location external workload profile in U-18 soccer players
Perfil multi-ubicación de carga externa en jugadores de fútbol sub-18

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Original Article

Proc IMechE Part P:
J Sports Engineering and Technology
1–8

DOI: 10.1177/1754337120972516
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What is the most suitable sampling frequency to register accelerometry-based workload? A case study in soccer

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Using an Inertial Device (WIMU PRO) to Quantify Neuromuscular Load in Running: Reliability, Convergent Validity, and Influence of Type of Surface and Device Location

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Original Article

Proc IMechE Part P:
J Sports Engineering and Technology
1–11

DOI: 10.1177/1754337118816922
journals.sagepub.com/home/pip
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Static and dynamic reliability of WIMU PRO™ accelerometers according to anatomical placement

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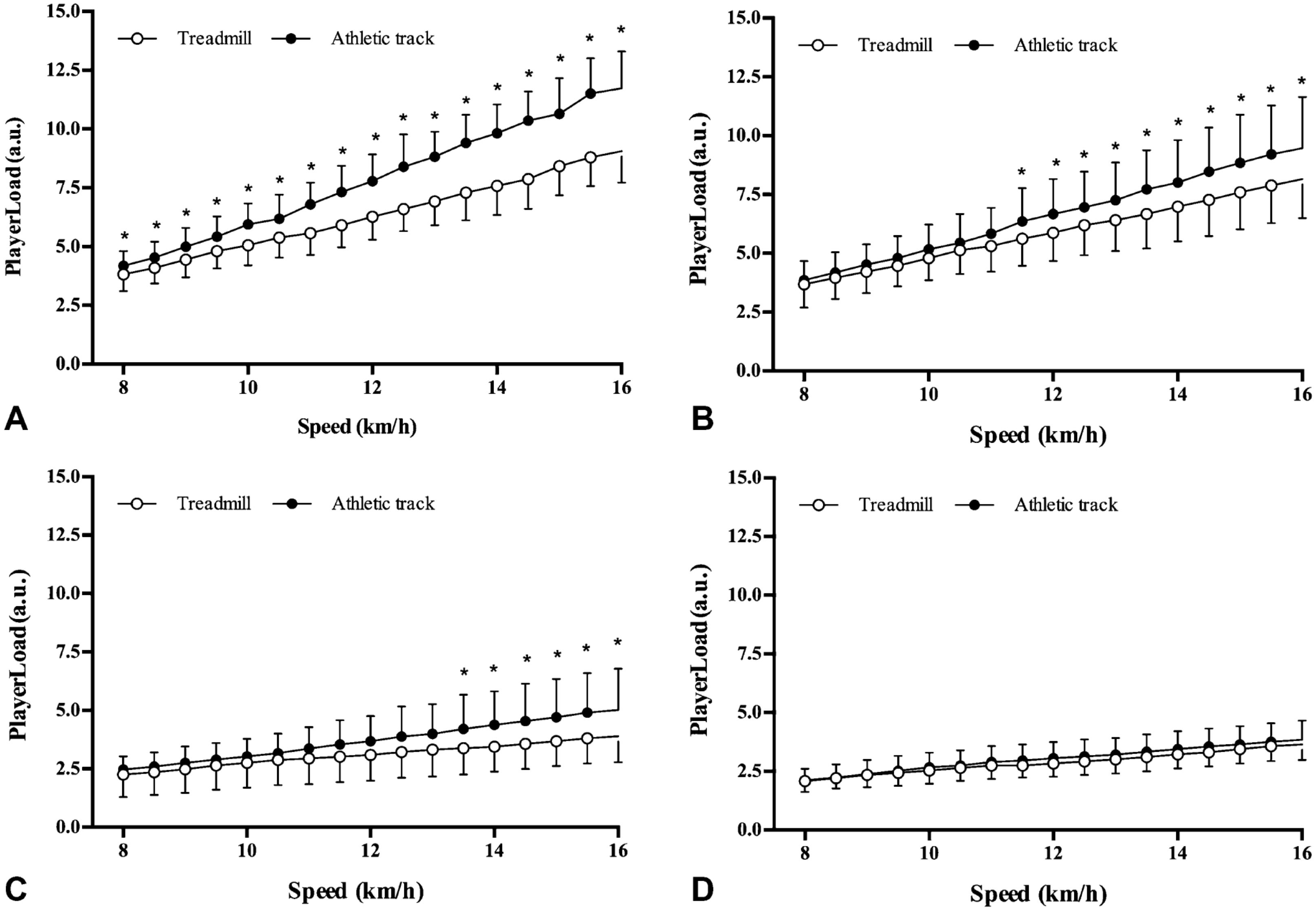


Figure 3. Dispersion plot with *SDs* and difference of means between treadmill and track conditions in PlayerLoad at 8–16 km·h^{-1} as a function of anatomical location of accelerometers: (A) ankle, (B) knee, (C) center of mass, and (D) scapulae. *Significant differences between treadmill and track ($p < 0.05$).

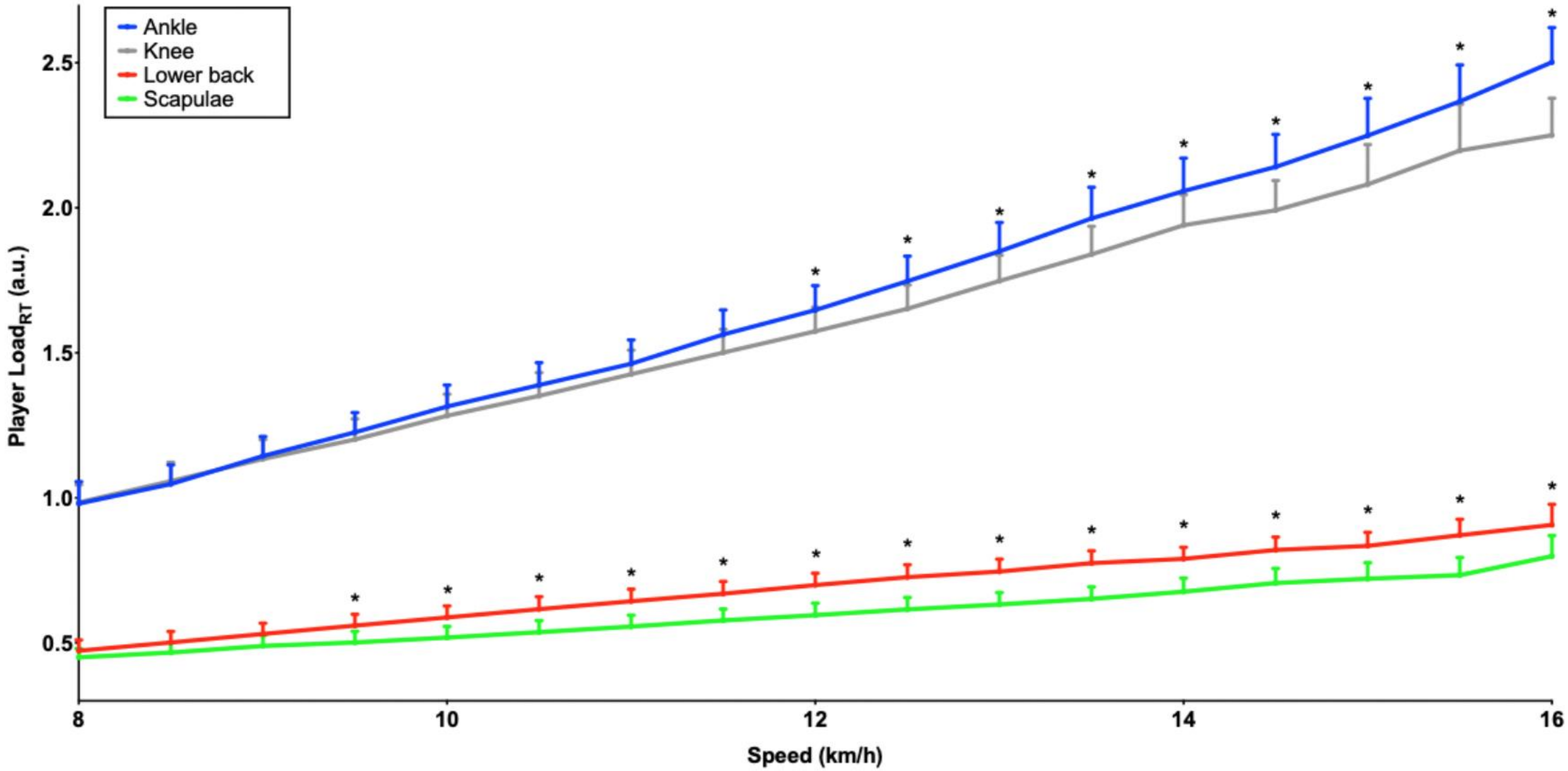
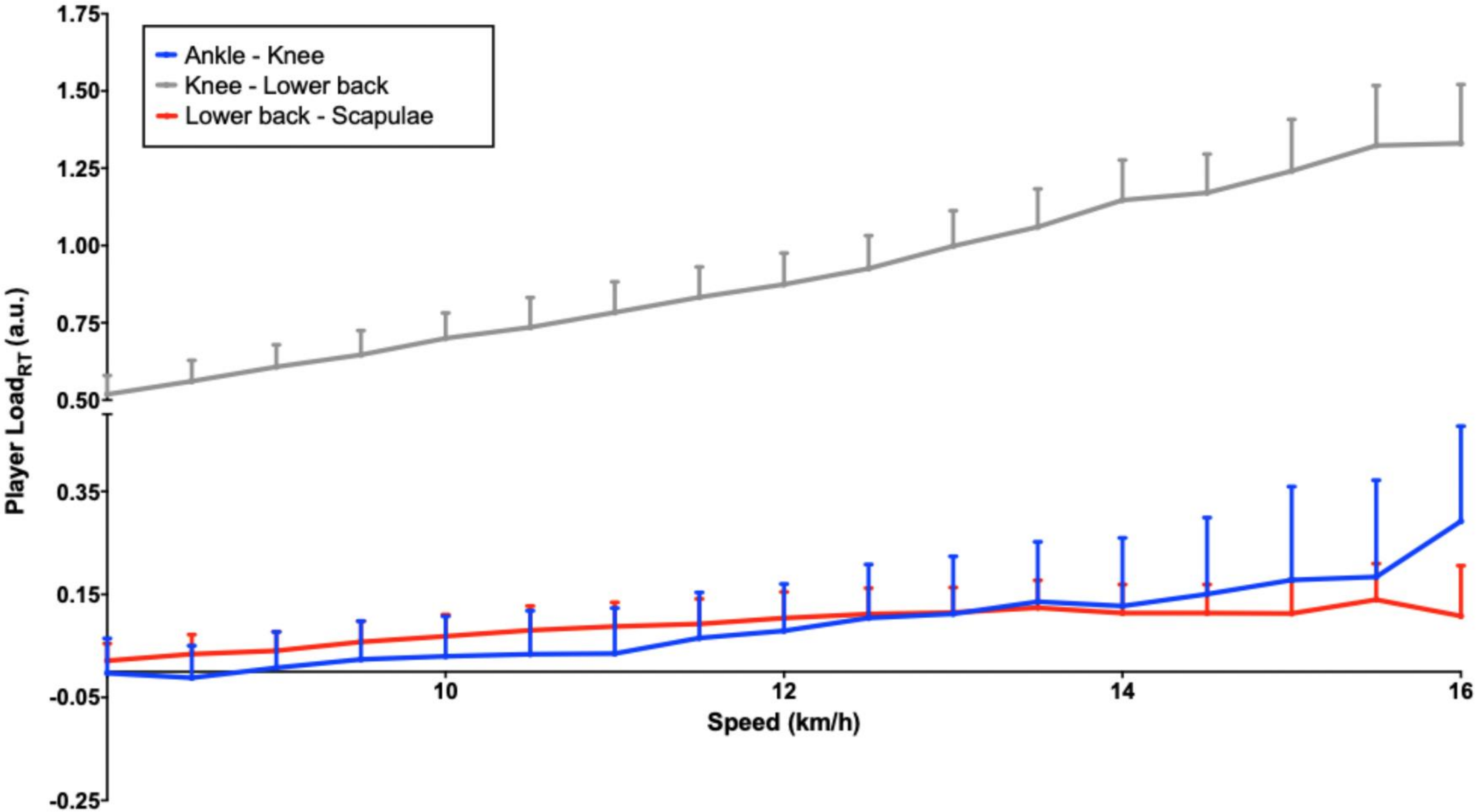


Figure 2. PL_{RT} dynamics of all the participants in the analyzed joints between 8-16 km/h.
*Statistical differences ($p<.05$).


Ankle - Knee
Knee - Lower back
Lower back - Scapulae
1.75
1.50
1.25
1.00
0.75
0.50
0.35
0.15
-0.05
-0.25
Player Load$_{RT}$ (a.u.)
10
12
14
16
Speed (km/h)

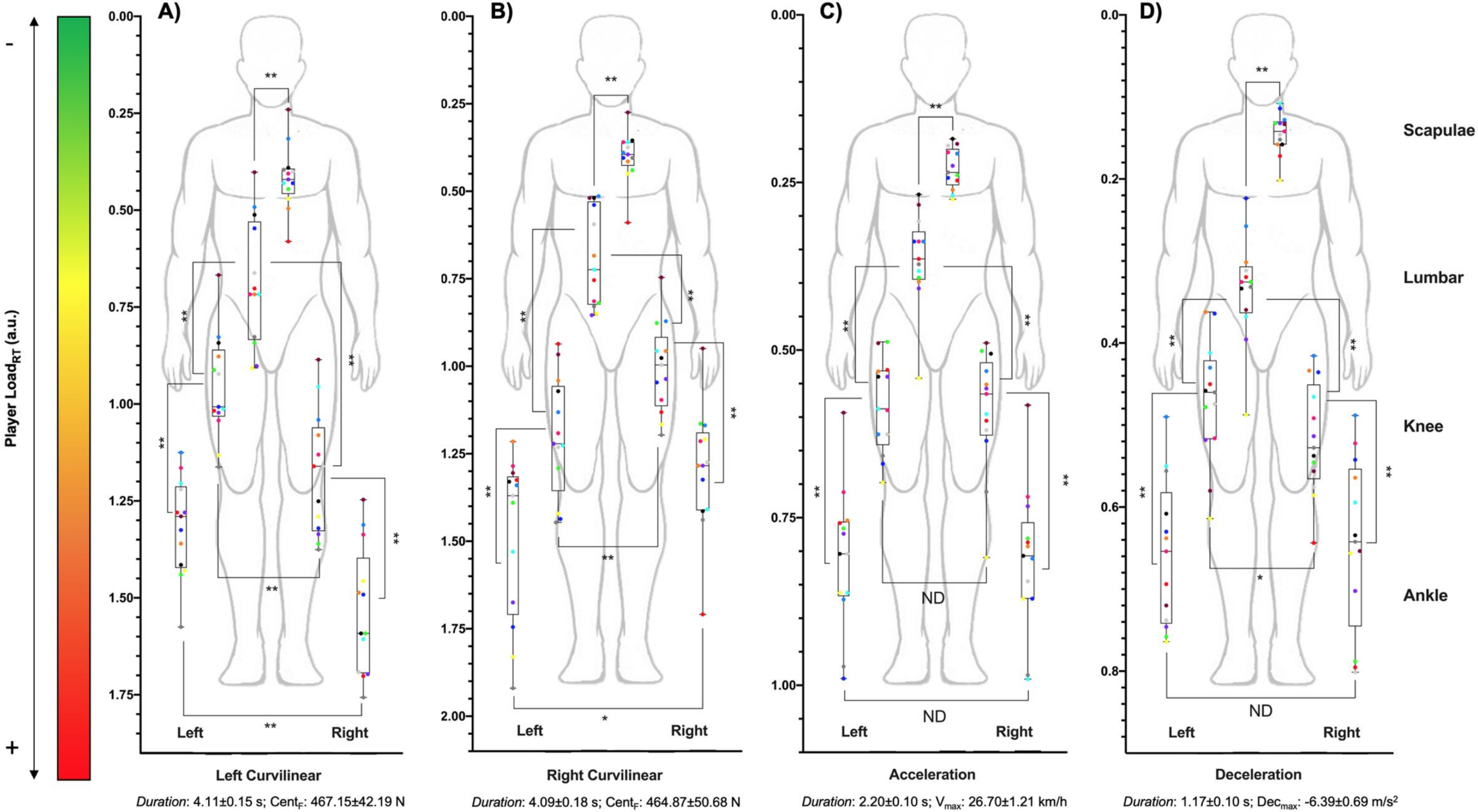


Figure 1. *Multi-location external workload profile of semi-professional male basketball players in curvilinear displacements (A: left and B: right direction) and speed changes (C: acceleration and D: deceleration). **Statistical differences (p<0.01); *Statistical differences (p<0.05); ND: No statistical differences.* 191 192

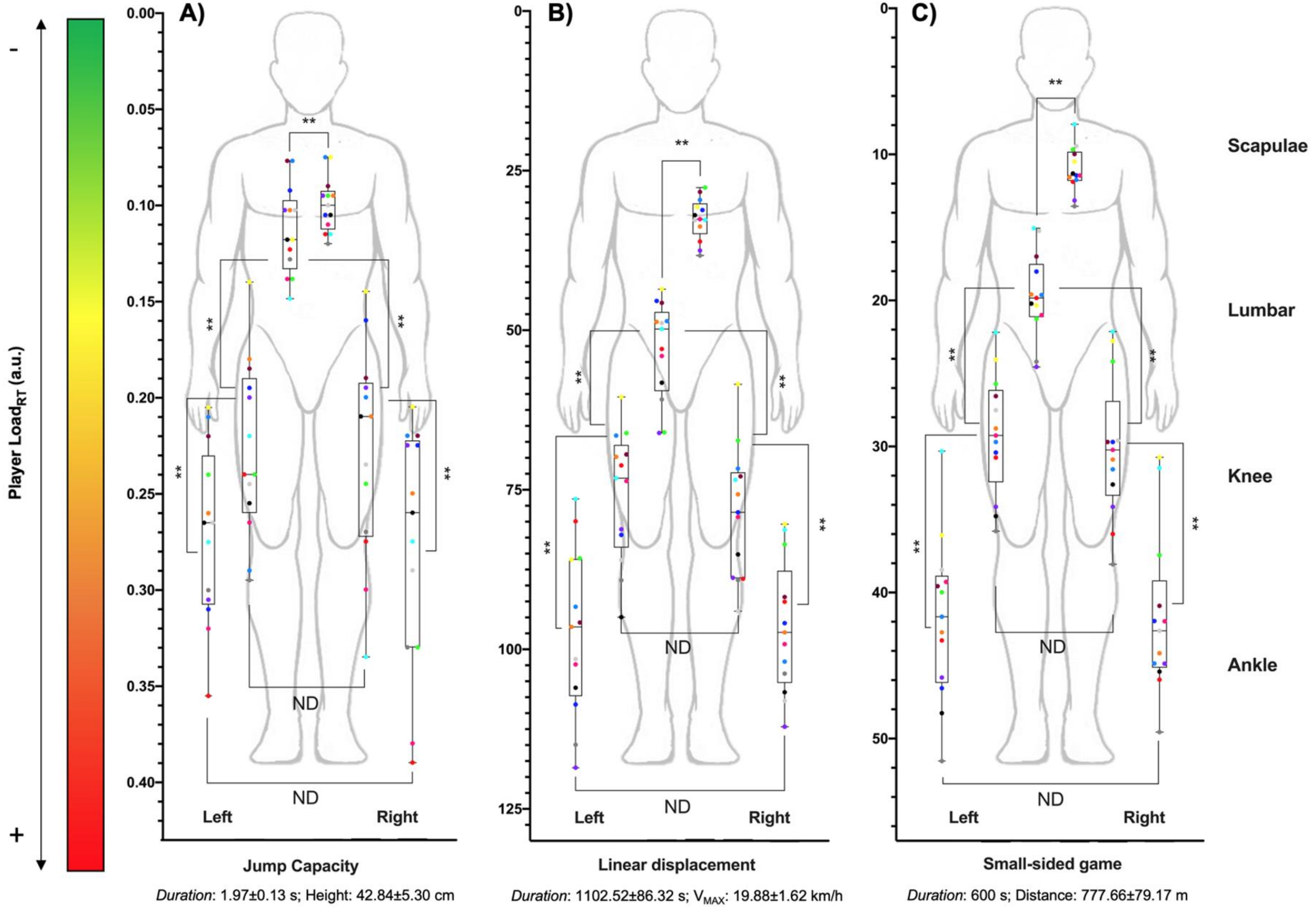


Figure 2. *Multi-location external workload profile of semi-professional male basketball players in (A) jumps, (B) linear displacements and (C) small-sided games. **Statistical differences ($p<0.01$); *Statistical differences ($p<0.05$); ND: No statistical differences.*

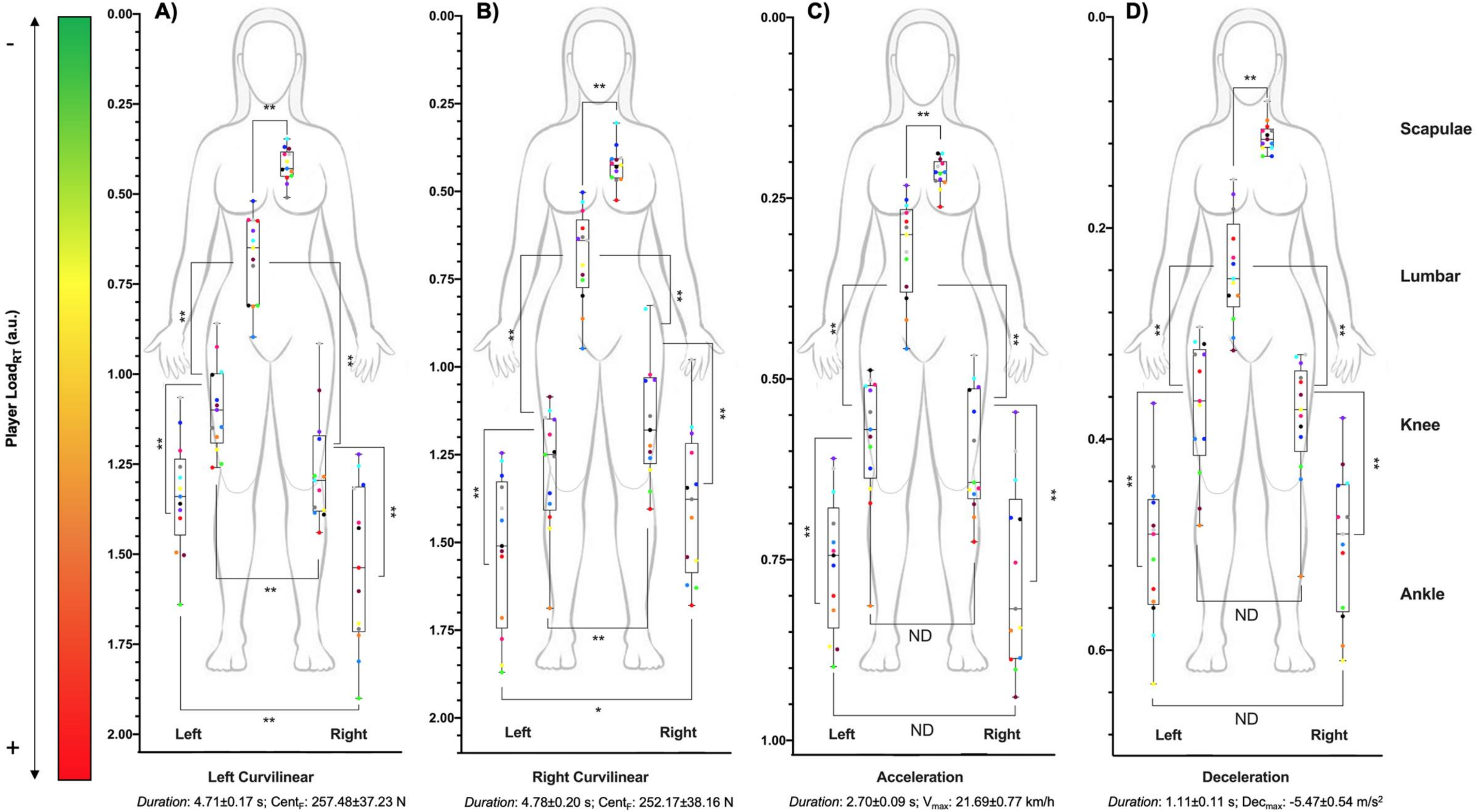


Figure 1. *Multi-location external workload profile of semi-professional female basketball players in curvilinear displacements (A: left and B: right direction) and speed changes (C: acceleration and D: deceleration). **Statistical differences (p<0.01); *Statistical differences (p<0.05); ND: No statistical differences.* 94 95

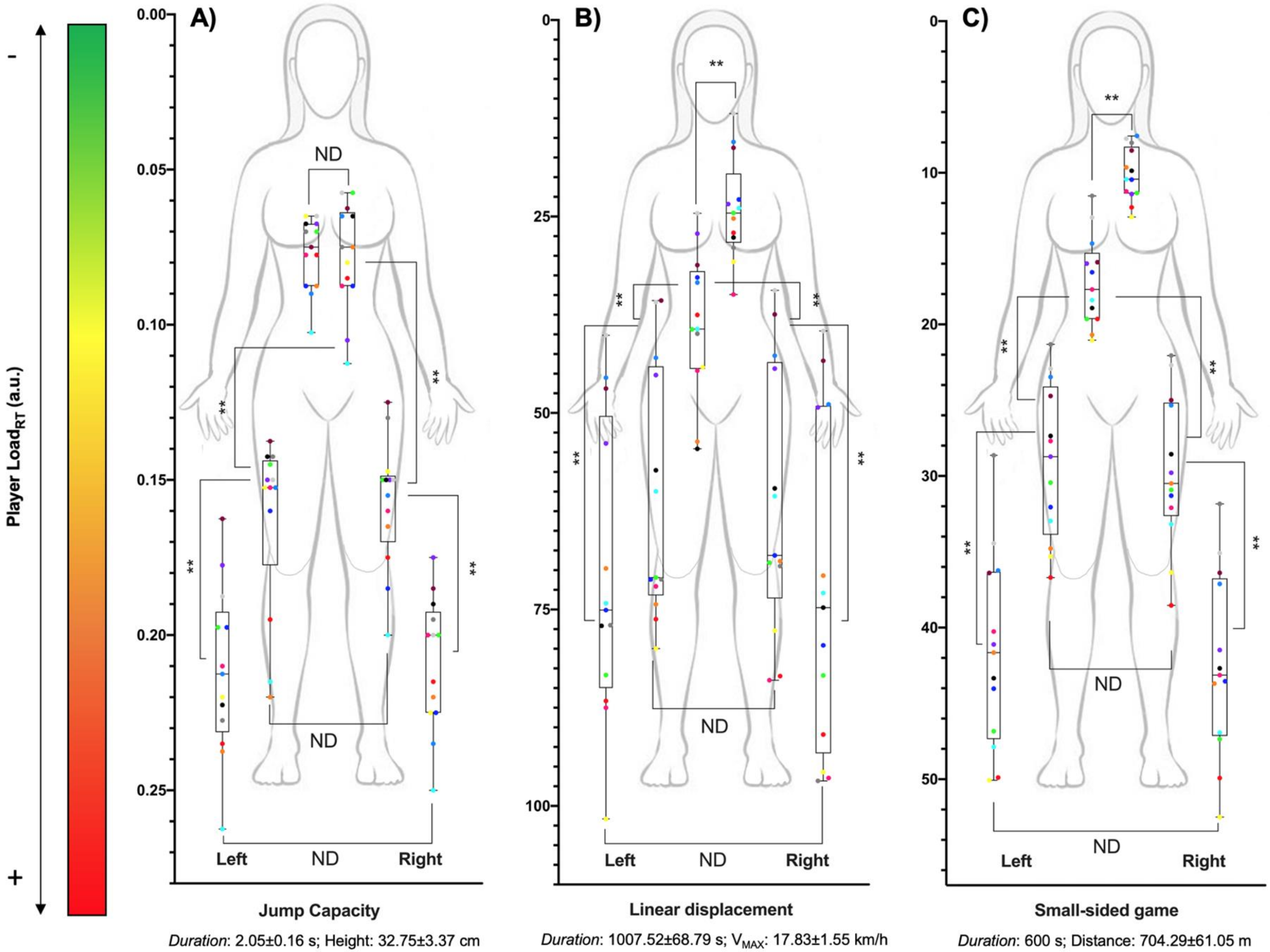


Figure 2. *Multi-location external workload profile of semi-professional female basketball players in (A) jumps, (B) linear displacements and (C) small-sided games. **Statistical differences (p<0.01); *Statistical differences (p<0.05); ND: No statistical differences.*

9. CONCLUSIONS

- ✓ Accelerometry has been developed as a new method for workload quantification in sports.
- ✓ Its precision and sensibility are higher than conventional electronic performance and tracking systems (GNSS, LPS or video-tracking).
- ✓ During its working and registering, different technical aspects and practical recommendations should be addressed to obtain the optimal accelerometry-based data.
- ✓ Thanks to accelerometry, neuromuscular load can be register and, from this data, it is possible to know the force executed by the athlete as a result of the interaction with gravity and the teammates/opponents.
- ✓ For accumulated workload, PL is the most used index and its normalization by time (PL/min) is employed to compare data independent of total duration of tasks/session.
- ✓ Scapulae is the most recommended location if tracking data would be register simultaneously. If not, the accelerometer should be located the nearest as possible to the evaluated body location/segment.
- ✓ Neuromuscular load (peak and accumulated) should be integrated as a new group of monitoring variables, especially due to the high associations with muscle damage biomarkers and injury risk.

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Muchas gracias!

¿Alguna pregunta?

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